
Conservation and Ecosystem Services

Small mammal responses to farming practices in central Argentinian agroecosystems: the use of hierarchical occupancy models

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Organic farming is more environmentally friendly than conventional agriculture, promoting greater levels of habitat heterogeneity. Field borders could be more suitable for biodiversity in agricultural anthromes. Small mammals are crucial in these anthromes due to their contribution to food webs and seed consumption. We used hierarchical multi-season occupancy models to assess the effect of organic versus conventional farming on multiple small mammal species in agricultural anthromes of central Argentina. We modelled detectability and increased precision of estimates, overcoming deficiencies of previous studies. Small mammals were seasonally surveyed in 70 field borders (conventional) and 63 (organic) during two years. We were able to include less frequent specialist species, detecting a positive relationship with organic management possibly because of higher habitat quality of borders. Vegetation volume was the most important explanatory variable in both managements. Species' richness was greater under organic management mainly in spring when the habitat quality differences with conventional management were the greatest. Spring is key for the rodent assemblage because of the beginning of reproductive period, when resource demand is important. We suggest that maintaining high quality border habitats, as those supported by organic management, could allow farmers to obtain economic profit while also contributing to biodiversity conservation. Considering the positive role that native rodents may have in some agricultural anthromes, the maintenance of high population numbers may be important for biodiversity conservation. The approach used in this study shows the importance of modelling imperfect detection, reducing bias in parameter estimates, and it should be implemented in similar studies.

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Native rodents are the main seed predators in areas representing distinct phases along an active restoration process in a neotropical savanna

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Land use conversion to agriculture and pasturelands may alter not only the abundance of seed-eating animals but also their role as seed predators and dispersers. We investigated the effect of landscape changes, including areas under restoration process, on seed predation by native rodents in the Brazilian Cerrado, the most diverse savanna of the world. We evaluated seed predation of two tree species (*Tachigali vulgaris* and *Copaifera langsdorffii*; *Fabaceae*) in five habitats: typical savanna (cerrado sensu stricto), abandoned pasture dominated by African grass *Urochloa decumbens*, and three environments representing distinct phases along an active restoration process (two, three, and four years after direct seeding of native species). We also evaluated rodent abundance in these areas. In captivity, we offered seeds of both species and of *Urochloa decumbens* to *Necromys lasiurus* (*Sigmodontinae*), the most abundant rodent in the study. Field tests with semipermeable exclosures indicated that small rodents were the main seed predators in all habitats. Only for *Copaifera langsdorffii* seed-predation rates differed among habitats, being higher during the rainy season in the native Cerrado and pasture. We captured 180 rodents belonging to five species, with a high dominance of *Necromys lasiurus* (ca. 95% of all individuals). Areas in more advanced regeneration process and native environments tended to show greater rodent richness, following plant community patterns. In captivity, *Necromys lasiurus* preyed upon all species offered. Our results suggest that the transformation of native areas in planted pastures and subsequent regeneration processes modify the abundance of small mammals in the Brazilian savanna but not their role as main seed predators. The abundance of this group is relevant for crucial ecological processes, such as seed predation and potential for reducing the establishment of introduced species. Season of seeding and rodent abundance must be considered in restoration projects in open-vegetation habitats such as savannas and grasslands.

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Research progresses on seed-rodent interactions in China

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Seed-rodent interaction has been recognized as one of the important components of the forest ecosystems. Seeds provide food to rodents which provide service of seed dispersal and regeneration. It is obvious that seed-rodent relation is composed of both predation and mutualism. Seeds tend to manipulate hoarding behavior of rodents to maximize the seed dispersal fitness by adopting a series of conflicting but well-balanced strategies of attraction and defense. Rodents tend to select seeds to maximize their fitness by adopting various hoarding behavior and seed management strategies. This reciprocal interaction would finally determine their ecological relationship shifting between predation to mutualism, and then the role of rodents in forest regeneration. Deforestation and forest fragmentation would greatly affect the seed-rodent interactions and then forest regeneration and health. There is a need to take actions of managing the seed-rodent interaction so as to facilitate recovery of degenerated forest ecosystems. Since middle 1990s, the seed-rodent interaction in six locations representing the tropical, sub-tropical, warm-temperate, temperate and cold-temperate climate zones have been carried out in China. This paper will present a review of research progresses on seed-rodent interactions in China.

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Effects of insect-infestation on rodent-mediated dispersal of *Quercus aliena*: results from field and enclosure experiments

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Rodents influence plant establishment and regeneration by functioning as both seed predators and dispersers. However, these rodent-plant interactions can vary significantly due to various environmental conditions and the activity of other insect seed-predators. Here, we use a combination of both field and enclosure (i.e, individual cage and semi-natural enclosure) experiments, to determine whether rodents can distinguish sound seeds from those infested with insects. We also demonstrate how such responses to insects are influenced by food abundance and other environmental factors. We presented rodents with two kinds of *Quercus aliena* seeds (sound and insect-infested seeds) in a subtropical forest in Qinling Mountains, central China, from September to November of 2011 to 2013. The result showed that rodents prefer to hoarded and ate sound seeds than infested seeds in the field and semi-natural enclosure, while they prefer to ate infested seeds than sound seeds in the individual cages. In addition, both hoarding and eating decisions were influenced by relative food abundance. Rodents hoarded more sound seeds in years of high food abundance while they ate more both sound and insect-infested seeds when food was less abundant. Compared with field results, rodents reduced scatter hoarding behavior in semi-natural enclosures and ate more insect-infested seeds in smaller individual cages. These results further confirm that rodents distinguish infested seeds from non-infested seeds but demonstrate that this behavior varies with conditions (environment and food abundance). We suggest that such interactions will influence the dispersal and natural regeneration of seeds as well as predation rates on insect larvae.

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Estimation of benefits and losses of seed scatter hoarding behaviour by rodents in a subtropical forest: implications for the evolution of mutualism in seed-rodent systems

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Seed hoarding behaviour of rodents plays an important role in seed dispersal and seedling regeneration of trees, as well as for the evolution of mutualism between trees and rodents in forest ecosystems. There are two opposite views on why rodents adopt a scatter-hoarding strategy: the pilferage avoidance hypothesis predicts that the cache pilferage rate should be very low to ensure benefits of cache owners, while the reciprocal pilferage hypothesis has an opposite prediction. Because it is difficult to identify seed hoarders and pilferers under field conditions by using traditional methods, the full costs incurred and benefits accrued by scatter-hoarding have not been fully evaluated in most seed-rodent systems. Our study aimed to test the two hypotheses at individual level under field conditions. By using infrared camera tracking and seed tagging methods, we investigated the comprehensive benefits and losses of scatter-hoarded *Camellia oleifera* seeds for three sympatric rodent species (*Apodemus draco*, *Niviventer confucianus* and *Leopoldamys edwardsi*) in a subtropical forest of Southwest China 2013-2015. We established the relationships between the rodents and the seeds at the individual level. For each rodent species, we calculated the cache recovery rate of cache owners, as well as conspecific and interspecific pilferage rates. We found all three sympatric rodent species had a cache recovery advantage (recovery rates > 50%) with rates that far exceeded average pilferage rates (<10%) over a 30-day tracking period. The smallest species (*Apodemus draco*) showed the highest rate of scatter-hoarding and the highest recovery advantage compared to the other two larger species. Across species, rates of scatter-hoarding and benefits were positively correlated with each other. Hence species having higher scatter-hoarding preference had higher competitive ability for seeds. Our results suggest that scatter-hoarding benefits the cache owners more in food competition, not the cache pilfers, supporting the pilferage avoidance hypothesis.

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Seed size effects on seed dispersal and predation by rodents at tree individual level

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Seed predation and dispersal by scatter-hoarding rodents play an important role not only on the seedling regeneration of trees, but also on the spatial distribution and structure composition of the whole forest communities. Both seed size and seed density have been found significantly affect the foraging preferences of rodents, which in turn influence the seed fates themselves. Current studies focusing on how seed size and seed density affect foraging behaviour of scatter-hoarding rodents mainly target one of two scales of comparison: the species scale, with comparisons of dispersal and predation of seeds from multiple species; or the individual seed scale, with comparisons among individual seeds from the same species. Even though individual variation in reproductive success within populations is a key component of evolutionary fitness, variation in seed dispersal and predation at the scale of individual trees is poorly understood. Our study asks how variation in seed mass and number among tree individuals affects the behaviour of animal dispersers and in turn the fitness of the trees. We first surveyed intraspecific variation in seed production of two *Fagaceae* tree species in a natural subtropical forest in south-western China. We then investigated how this variation affects seed predation and dispersal by scatter-hoarding rodents, which were the primary seed dispersers/predators. We weighed and then followed the fate of 11,618 seeds from 54 tree individuals to determine their survival and, if they survived, the distance they were dispersed. Our results showed a large variation of seed production among individuals in both tree species, including number of seeds, mean seed mass, the coefficient of variation (CV) of seed mass. The total number of seeds, the CV of seed mass and the crown size significantly affect the seed fates among tree individuals, but their effects differed between tree species.

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Forest fragmentation alters seed-rodent interaction networks: implications for rodent management

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Forest fragmentation has caused remarkable changes in species diversity and composition. However, it is still unclear how forest fragmentation affects the structure of interaction networks between rodents and plant seeds. In forest ecosystems, the interaction network between rodents and tree seeds is an important ecological network, and it plays an important role in the maintenance of biodiversity and service and function of ecosystem. In this study, we investigated how the interaction network between rodents and tree seeds was altered under forest fragmentation in a subtropical region in the Dujiangyan region, Sichuan Province, China. We studied the seed-rodent interactions in 14 secondary forest patches that ranged in area from 2 to 58 ha, and in succession stage from 10 to at least 100 years old. We measured the visit frequency (interaction strength) of rodents eating or hoarding seeds in each patch during 3 successive years, using seed tagging and infrared camera trapping, and calculated the metrics of the seed-rodent networks. We found that the seed-rodent interactions and population abundances of seeds and rodents mainly changed with stand age, not patch size: older patches had lower connectance and interaction strength, but higher nestedness. Connectance and interaction strength decreased with increase of metabolic per capita seed availability, while nestedness increased with increase of seed richness, but decreased with increase of rodent abundance. Seed coat thickness and starch contents had significant association with network metrics. Our results indicated that higher abundance of rodents and lower abundance of plant seeds contributed to higher interaction strength but lower nestedness of the seed-rodent interaction networks at early succession stage. Therefore, in order to facilitate the restoration of degenerated forests, it is necessary to take some intervention measures to protect the scatter-hoarding rodent species and reduce the invasion of farmland or commensal rodent species into the forest patches.

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Lead (Pb) bioconcentration in cestode parasites (*Hymenolepis* spp.) of rats (*Rattus* spp.) and their potential as indicator of heavy metal contamination in terrestrial environments

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There is a dearth of information about the use of parasites as indicators of lead (Pb) contamination in various terrestrial environments. In this study, *Hymenolepis* spp. from *Rattus* spp. samples collected in Los Baños, Laguna were subjected to lead concentration analysis. Rat samples were infected with intestinal cestodes, *Hymenolepis diminuta* (35.6%), and *Hymenolepis nana* (34.4%), and the liver parasite, *Taenia taeniaformis* (48.9%). Cestode prevalence was highest in *Rattus norvegicus* at 68.4%. Lead concentration (ppm) was observed to be highest in rats from agricultural sites, followed by residential rats, and lastly by forest rats. A higher lead bioconcentration factor (BF) was revealed in *Hymenolepis* spp. than in the rat host's intestine, kidney, and liver; however host muscle tissue had higher lead BF. No significant difference ($p=0.612$) in Pb concentration was observed between infected and uninfected rats. Lastly, a weak correlation between parasite burden and Pb concentration in rat tissues was observed ($r=0.140$). This study reveals that *Hymenolepis* spp. could bioaccumulate lead in rat hosts. However, it may not be as sensitive as other parasites observed in other host-parasite relationships. It is recommended to conduct laboratory experiments to establish the potential of intestinal parasites of rats to influence accumulation of heavy metals in the animal host's tissues.

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Changes in rodent burrow abundance and distribution in grazing ecosystems of southern Russia under human-induced landscape transformation from the desert to steppe

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Rodents play an important role in rangelands through the engineering of extensive burrow systems, which provide key habitats for many animal and plant species. We have analyzed the long-term pattern of variation in the abundance and distribution of rodent burrows in grazing ecosystems of southern Russia under the landscape change from the desert to steppe caused by the drastic reduction of livestock after the collapse of the USSR in the early 1990s. We surveyed burrow distribution by counting burrow openings of each rodent species in 100-m segments of 19 3-km transects, totaling 57 km surveyed. We estimated burrow density, the length and the fraction of segments with and without burrows as measures of habitat quality, size, isolation, and connectivity. We performed surveys in 1980 ("the desert period") and repeated them in 2017 ("the steppe period"). We found drastic changes in the burrow abundance and distribution of keystone rodent species, as well as the evidences of desert habitat fragmentation and isolation caused by the expansion of tall-grass communities and overgrowing of sands. Burrows of the open-dwelling ground squirrel, *Spermophilus pygmaeus*, the dominant and keystone species during the desert period, almost disappeared from the rodent burrow complex by 2017, which indicates significant habitat loss. On the contrary, the burrows of the folivorous social vole, *Microtus socialis*, which was rare in 1980s, became abundant and ubiquitously distributed. Burrow density of the desert-dwelling psammophilous midday gerbil (*Meriones meridianus*), as well as the size of occupied patches decreased, while the inter-patch distance increased, indicating habitat fragmentation and isolation. Burrows of folivorous tamarisk gerbil (*Meriones tamariscinus*) were recorded only sporadically in both 1980 and 2017. The observed drastic changes in the rodent burrow complex, the keystone element of grazing ecosystems, can have long-term and important consequences for the dynamics of local rangelands and their sustainability.

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The potential of small and medium mammalian carnivores to mediate rodent pest damage in commercial agriculture

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Rodents remain a key pest of grain crops globally. However, the use of chemical control to manage rodent populations is problematic due to increased rodenticide resistance in rodents and negative environmental effects. This has sparked interest in ecologically based rodent control (EBRM). Predation is a key component of EBRM that is often neglected. In this study we aimed to evaluate the potential of predation to mitigate rodent pest damage in commercial maize fields in the Free State Province, South Africa. We used camera trapping to quantify the occupancy and species richness of small mammalian carnivores. We used live trapping to assess rodent densities, and snap traps to investigate rodent diet. Finally, we applied a crop simulation model (APSIM) to estimate the effect of varying plant densities (which act as a proxy for varying rodent densities) on crop yields. Camera trapping studies showed that at least 8 mammalian carnivore species frequented the cropping areas, of which 6 species preyed on rodents. Grain damage was impacted by rainfall, planting density and the amount of seed incorporated in the rodent diet. The greatest impact of rodent seed damage (2-40% yield decline) occurred under high rainfall and densities of 10-30 rodents/ha. In contrast, under low rainfall, seed damage was less prevalent. In low rainfall seasons crops are severely limited by available soil water, and seed damage (up to 20%) will not affect crop yield, as the remaining crops have more water and can compensate for the seed losses with increased yields. Seed impact will only become evident at rodent densities 30-100 rodents/ha. Therefore, rodent densities up to 30/ha can be of concern, especially under ideal climatic conditions. Our results show that the combined predation of mammalian carnivores have the potential to significantly impact rodent biomass, and hence alleviate crop losses.

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Rodents as indicators of the ecological impact of an open-cast iron ore mine in the Northern Cape, South Africa

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Rodents have been proposed as an important ecological indicator in various environments. In general, it is expected that rodent community structure change with varying levels of succession and habitat disturbance. In this contribution we report on the results of the first seven years of a long-term biomonitoring study, using small rodents and vegetation to measure ecosystem change on an open-cast iron ore mine. A total of 43 transects on the mine and surrounding farms were stratified to be at various distances and along a potential impact gradient radiating from the core mining activities. Wind speed and direction, vegetation units, sensitive plant areas and conservation areas were also taken into account. All transects were sampled annually at the end of the main rodent breeding season. Clear changes in both the plant and rodent communities closer to the mine activities were observed, with some transects already showing significant changes within the first year or two after mining commenced. These included 1) a decrease in rodent and plant species richness, 2) a disappearance of “specialist” rodent and “decreaser” plant species (generally associated with higher habitat integrity), and 3) a decrease in both plant and rodent species diversity. Similar changes were less apparent on transects further away from the mining activities, but were not observed on the furthest, least influenced, transects. A strong relationship between veld (vegetation) condition scores and total herbaceous dry matter production, and rodent species richness, diversity and indicator species’ presence/absence were found, demonstrating the potential value of small rodents as ecological indicators of ecosystem integrity.

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Rodents and their role in habitats in an tropical Africa context: the case of the DR Congo

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Rodents are a pervasive, yet interesting group of mammals when considering their role in ecosystems of either natural or agricultural lands. While playing an important role for ecosystem services, many species are known as pests in agriculture or can pose a serious problem for human health. We studied the role of rodents in agricultural lands and natural ecosystems (primary and secondary forests) by analysing the stomach content of animals captured at different sites, supplemented by literature data for the same areas. Our results show that the abundance of a species was not associated with damage to plant species according to stomach contents. We found an interesting role of rodents in seed dispersal. While there are no records in the wild for many species, some others showed useful effects for ecosystems; these comprise squirrels (e.g. *Funiciurus*, *Heliosciurus*, *Protoxerus*) or mice and rats of the genera *Malacomys*, *Lophuromys*, *Grammomys*, *Deomys* or *Cricetomys* for which stomach contents revealed the presence of pest or nuisance species for plants such as centipedes and millipedes or termites that destroy crops by breaking the germinating young plants. Some species of *Hylomyscus* or *Xerus* play a role in plant pollination as they feed on nectar, while many others play a role in the food chain as prey or by feeding on other species. The damage caused by rodents is linked to eating bird eggs, some mammal species, birds, reptiles or frogs apart from the known role of pest they have in agriculture or as disease vectors. Despite the controversy in balancing the ecosystem services and disservices, rodents play structural roles in ecosystems for example, by pruning or eliminating vegetation types, spreading seeds, competing with other animals or spreading diseases.

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A valued rodent (*Rattus exulans*) population assessed for cultural harvest

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Kiore (Pacific rat, *Rattus exulans*) arrived in New Zealand with Ngatiwai, a Maori tribal group in northern New Zealand, and as such are culturally important in Ngatiwai histories and traditions. Kiore are a bioindicator, a traditional source of skins for cloaks, and one of many traditional foods. However, ecological and social contexts for this species have changed dramatically over the last 150 years. Once common, kiore are now restricted in their numbers and range, and widely regarded as pests in New Zealand. To safeguard cultural access to kiore, tribal environmental managers seek to understand and monitor the abundance and health of remaining kiore populations. To assist, we assessed body condition, reproductive status, and parasite and disease loads of kiore on one of the few remaining island populations within the Ngatiwai tribal area. We also compared detection devices to determine device suitability for ongoing monitoring of relative abundance. Of 16 kiore caught, body condition was similar to that recorded in studies on other New Zealand islands. Inflammation of the liver and/or bile ducts was present in 38% of captured kiore, attributed to the common nematode parasite *Capillaria hepatica*. People harvesting kiore can take precautions to prevent transfer of this parasite to humans. Subcutaneous fat levels were moderate, and lower in diseased individuals, especially females. Capture rate in live-traps was 19.3 kiore per 100 trap-nights, higher than in snap-traps (1.4). A one-night kiore tracking rate in inked footprint tunnels was 25%, and a one-night camera-capture index was 44%. Because live-trapping had a relatively high capture rate, permits inspection of animal condition using traditional and other methods, and enables release of juveniles and non-targets, it appears to be the most useful method for ongoing abundance assessment.